H. Butterfield — Man on his Past — Historiography

R.G. Collingwood — The Idea of History

H. Finberg (ed.) — Approaches to History
(R. Hall on Hist. Science)

Distinguish Historiography — art (science?) of writing history

Methods of History — evaluation of historiographical procedure.

5 views

1.) Propagandism — early 18th Cent. history
2.) Fact-getting — 1st stage of positivism (Comte)
Ranke & Acton — philological evaluation of sources — external + internal evaluation.
3.) Positivism — general laws of history cp Marx, history as social science, Toynbee etc.
4.) Empathetic history — Collingwood, subjective problem situation
5.) Situational logic applied — Popper.

See also

P. Gardener (ed.) 1974
To Philosophy & History
(Oxford Readings in Philosophy)

Nagel: The Structure of Science ch 15.

HISTORY I

Greek Science (cp Cohen & Drabkin: A Source Bk in Greek Science)

Presocratic Speculative views of the nature of matter and the universe.

Hesiod & Homer — Mythos (myth) replaced by Logos (reason).

Ionian School (Miletus) — Thales (c624-565 BC) Everything made of water

Anaximenes (Ion c.570 BC) - - - air

Anaximander (611-547 BC) Doctrine of the Apeiron.

Pythagoreans (b. c.582 BC) number mysticism

Eleatic School (S. Italy) Parmenides (fl. 501-492 BC) change an illusion
Zeno (fl. 464 BC) (paradoxes to show that change and plurality are contradictory)

Heracleitus (c540-475 BC) Everything is in flux.

Sicily — Empedocles (c.500 - c.430 BC) Earth air fire & water - secondary elements.

born Ionia → Athens — Anaxagoras (478 - 428 BC) infinitesimal atoms, seeds.

Atomists

Nature — Leucippus fl. c. 475 BC.
Democritus c. 470 – c. 410 BC.

Socrates (470–399 BC.)

Plato (427–347 BC.) (dialectic – Wakefulness of Forms & Ideas – Reality)

Cosmogony discussed in Timaeus
– Mathematical atomism
Founded the Academy.

Post-Plato

3 main schools

Epicurus (342–270 BC.) followed atomism
↳ Lucretius (c. 95–55 BC.)

Stoics (believed in the Cartesians)

Aristotle (384–322 B.C.) the Peripatetics
↳ dominated scholastic philosophy and science down the Copernicans & Galileo
– worked with Christian theology

left Athens shortly before his death
when indicted for 'impiety'.
"Athens shall not sin twice again
Philosophy"

& St Thomas Aquinas (1225 - 1274 A.D).
(and by Averroes (1126 - 1198 AD) with Islam)
I shall concentrate on

Aristotle (384 BC - 322 BC) born in Stagira

Studied under Plato until Plato's death in
tutor to Alexander the Great.
Founded the Peripatetic school.
(with Lyceum)

Main works

Organon : Books on Logic
(Instrument of thought)
Posterior Analytics (Socrates Plato)
First principles induced from experience by intuition. Bk II ch. 19.

Philosophy — The Metaphysics
Matter & Form.
doctrine of potentiality

Physical Science

change in space — The Physics (Physica)
locomotion in heavens & on earth — On the Heavens (De Caelo)
qualitative change — On Coming-to-be & Passing-away (De Generatione et Corruptione)
Forced change? in the atmosphere. — Meteorology (Meteorologica)

+ Biology, Psychology, ethics,
politics etc.
Collected works ed. Ross.

See also G. Lloyd: Aristotle: The Growth & Structure of his Thought

and the classic
W. Jaeger: Aristotle: Fundamentals of the history of his Development
(gradual shift away from Plato)

Standard Greek edition by Bekker:
$130^a 12$ means line 12 of first column a of p. 130 of Bekker edition

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Metaphysics concerned with Being
See Met IV ch 1, $1003^a 17$
(p731)

Physics concerned with change through 'nature'
– essential change (this does not mean change in essence)
N.B. Aristotle is concerned with observation, not with experiment

Books cited

Neugebauer (3 Vols) : Astronomy in Antiquity

Commentaries by Ross: Aristotle

and Solmsen: Aristotle's System of the Physical World

See also chapter on Aristotle in

S. Sambursky: The Physical World of the Greeks.

and Cohen & Drabkin A Source Book of Greek Science

Aristotle's Physics is very much concerned with change (~~a movement~~ in a ~~general sense~~)

3 sorts of ~~Movement~~ change

① Coming-to-be and ② passing-away
and ③ movement (or process)
~~alteration in quality~~

~~local motion (change in place~~
~~— also change in size~~)

Aristotle is opposed to Parmenides
(Nothing changes because change
involves 'what is' coming from what
is not, and how can 'what is not'
be the 'source or ground of 'what is'.)

He is also opposed to the Atomist doctrine
in which particles do not change but only

cf Phys p. 81

Motion as an actualization of that which is potential, as such is. If there is something which is actually x and potentially y, motion is the making actual of y - as such

* 3 types of Movement:

alteration as quality / change in quantity (S139)
or place (locomotion)

N.B. A. after use Movement to include generation / destruction and as general means & alteration changes in accidental qualities, not substantial / essential changes, which to would denote as generation / corruption.

spatial arrangement. In particular Aristotle denies ~~the~~ 'void' (see below)

Aristotle's solution to the problem of change is as follows:

Substance = Matter + Form.

(Prime) matter is potentially of form as matter acquires form it becomes a determinate, differentiated 'thing' i.e. it becomes not potential substance but actual substance.

Change = Fixed matter + changing Form.

Forms or attributes are either *essential*, man is a rational animal

or *accidental*, Tom is a musician

change is either ~~[illegible]~~ *essential* (i.e. in virtue of something's nature),

*movement or process { ← generation Form comes into being, ~~alteration~~. ~~essential~~ form changes (contrary) corruption or decay Form disappears. (contradictory)

~~But~~ or change is accidental

Tom starts playing the trumpet

But not-being is not a difficulty since forms are present *potentially*

note earth → fire is generator
because cond is = prevalent of hotness

The acorn is potentially the oak tree

The Musician can potentially play the trumpet and so on.

This doctrine of { matter and form / Potentially + actually

is explained in the Metaphysics (Bk 9)

Aristotle wants now to examine what produces change (or movement or motion in the generalized sense)

He explains in The Physics his doctrine of the 4 Causes (Physics BK II Ch. 3.)

	Ex Statue
1.) material	marble
2.) formal	shape
3.) efficient	chisel
4.) Final	production of a work of art.

└> Teleology.

In his chemistry Aristotle argues that ~~the~~ ~~Empedo~~ cleon elements earth air fire and water can change into one another. because each element contains forms, which can come and go

Thus ~~Fire~~ Earth = cold + dry.
air = hot + fluid
Fire = hot + dry.
water = cold + fluid

In regard to local movement (our ordinary idea of motion) Aristotle describes a theory of, space and time

Space and time are continuous.
i.e. infinitely divisible so indeed is matter (as against the atomists) but the total universe is finite in extent and quantity of matter.

This is because ∞ divisibility = potential infinity

which A. allows
but ∞ extent and quantity would be a completed infinity
which A does not allow.

But Time is ∞ in both directions since all instants do not coexist this is not an example of completed infinity. (Conflict with theology of Plato universe created (Timaeus))

Aristotle's Cosmology

wheels 55 in all (Metaphysics Bk 12 ch 8) (p. 883)

Crystalline sphere carry planets round a spherical stationary earth. (Borrowed from Eudoxus, but now take literally)
Perfect motion is circular
— Natural to aether, the 5th element of which the stars are made.

In sublunary region we get change and decay and different laws

cf. Newton

Mass × Acceleration = Force − Resistance

N.B. Aristotle does not say
a heavy body in the void
moved more faster than a
lighter body.
In the Void they all move
at the same speed

See p. 236
Physics Bk II, ch 1.

N.B. If a body is thrown it explodes because of action of air (which also causes resistance) If in a void no motion is possible! (A void is looked for notice)
Physics Bk IV ch 8 (p. 254)

Natural motion too is in st. line. earth goes downwards, fire goes away from centre.

But natural motion can be perturbed by force or unnatural ~~irregular~~ motion eg the motion of a projectile.

Aristotle's Law of Motion (Physics Bk IV ch 8 (p. 284) But cf. Bk VII ch 4 (p. 353) minimum force required)

$$\text{Velocity} = \frac{\text{Force}}{\text{Resistance}}$$

(cf Newt. Acc. = Force − Resistance)

If resistance → 0, Vel. becomes infinite.
This is one of A's powerful arguments against the void.

For A. explanation in science is to identify the 'nature' or substantial form of a body and the destiny that Nature will endeavour to fulfil.

But every property of of a body, magnetic extent e.g. becomes, in scholastic development of Aristotle, associated with its own form.
Explanation in terms of forms becomes circular.

cf Opium causes sleep in virtue of a dormative principle (or form)

But only evidence for this power is the outcome it produces.

Additional points

A. believes in chance, denies fatalism of argument of the sea-battle in De Interpretatione ch. 9. , Physics ~~ch~~ Bk II Part C

~~Sea battle will occur or~~
Sea battle will occur or not occur.

Does this mean that that the battle will occur or will not occur.
i.e. is the occurrence or non-occurrence of the sea-battle determined as well as determinate

B The Unmoved Mover (God) is source of the motion of the outermost sphere.
Physics Bk 8.

Other spheres are moved by 'intelligences' (angel's?) Relation to the Primum Mobile not at all clear in Aristotle.

Mechanics after Aristotle

Contributions to statics by Archimedes &
the greatest of all the Greek geometers and
mathematicians.

Contributions by Archimedes (c.287-212 B.C.) (Syracuse)

1.) Theory of the lever in 'On the Equilibrium of Planes'

2) Archimedes' principle, or hydrostatics
— theory of floating bodies, 'On Floating Bodies'

3.) Method of exhaustion — calculation of the integral of the area. (Quadrature of Curves)

4.) Practical inventions Archimedes screw
War machines etc.

5.) Notation for very large numbers
The Sand Reckoner.

The Alexandrian School

Euclid (c. 330-260 B.C.)

Apollonius (c. 220 B.C.) — Conic Sections

Hero (A.D. 62) (Pneumatics, Automata)

Ptolemy (C. A.D. 140) (The Almagest) — Calculation of Earth's circumference. Solid sphere in sun.

The Romans

Lucretius 'On The Nature of Things' combines
(c. 95-55 BC) atomism & Epicurus.

Pliny (23-79 A.D) Natural History in 37 Books -
first universal treatise of
science, Medieval

Heraclides of Pontus (c. 388–315 BC) rotation of earth
⇓
Aristarchus (of Samos) (c. 310–230 BC)
Heliocentric theory — taught at Alexandria.

Hipparchus (c. 190–120 BC)
discovered precession of the equinoxes

cf also
Eratosthenes (c. 276–c. 194 BC)
estimated size of the earth
— really a geographer. (but also a mathematician — cf Sieve for prime numbers)

The Dark Ages 500 A.D – 1000 A.D.

Greek manuscripts preserved in Byzantine Empire (the Eastern empire)

But classical Greek is quite different from Byzantine Greek!

The Culture not really transmitted to the West until Conquest of Constantinople by the Ottoman turks in 1453.

In Europe Greek philosophy, science at second hand, lord Commentaries on Encyclopaedias (cf Venerable Bede)

The Greek Texts of Aristotle came to the West in 11th–12th Centuries by translation from the Arabic.

Arabic Science translated Aristotle into Arabic.

Averroës, Spanish Moor (1126–1198) known as the Commentator

cf. also Avicenna Persian Islam (980–1037) philosopher, physician

Other major figures, particularly in Optics

Alhazen (965–1038) developed the ideas of

Alkindi (813–880) ←

Also Albiruni (973–1048), whose astronomical works have still not been translated (cf Ramjidsfoor at Chelsea).

Arabic texts became known in the West after the defeat of the Spanish Moors, resulted in the great explosion of translation of the philosophical & physical treatises of Aristotle.

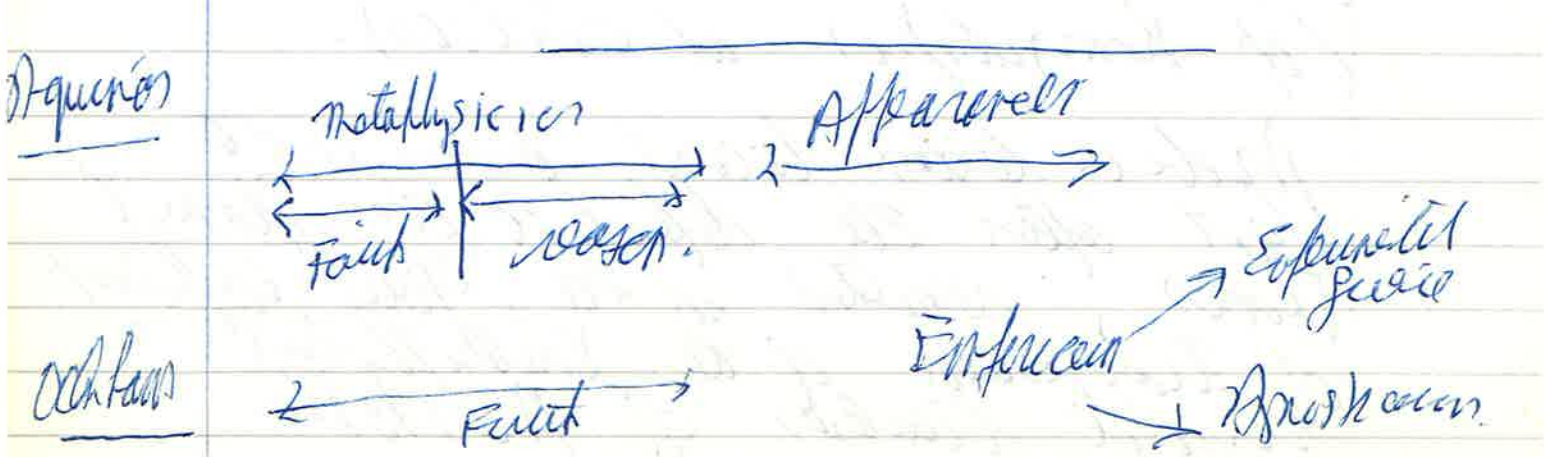
Practical Reasoning in the Middle Ages

1.) Lenses
2.) Compass.
3.) Printing.
4.) Clocks (escapement)
5.) Gunpowder (+ other classical knowledge.

~~Myth~~ Aquinas allows some knowledge beyond apparent by reason.

Franciscans reject role of reason in theological matters

cf. { Duns Scotus
Roger Bacon
William of Ockham.



The Classical literature was not translated in the main until the Renaissance (15th, 16th century).

Also Archimedes was not translated entirely until the 16th century

13th Century

St. Thomas Aquinas (1227–1274) Dominican attempt to reconcile Christian theology and Aristotelian philosophy
when they disagreed Faith is to be preferred to reason

Eg. ① Cosmos is created, not existing to −∞.

② Transubstantiation Bread, wine are forms without substance → body, blood of Christ — not founded by Aristotle

i.e. form of bread 'disguises' the body of christ.

③ Nature is regular – no room for miracles

[④ Aristotle also taught that the Soul did not survive the body]

Attack on Aristotle

Condemnation of Paris (1277)

To 'prove' anything by philosophy is a constraint on God's power to do anything

Truth can only be known by Faith.

Science should restrict itself to 'appearances'
→ Empiricism, Nominalism

[Another strand here was emphasis on experiment:

Robert Grosseteste (c.)1175–1253)

Roger Bacon (c.)1214–129~~4~~2)]

But the main philosophical route to empiricism was via

William of ~~Occam~~ Ockham (c. 1280–1349).

Nominalist, Empiricist, Ockham's razor against 'metaphysical' explanations.

↳ we never know reality beyond appearances except by Faith

cf ~~[illegible]~~ Nicholas of Autrecourt – a medieval Hume. (c.1300 – c.1350)

↳ Saving the appearances' or 'phenomena'

Science no longer engaged in search for Truth

– no physical reality claimed for alternatives to Aristotle

there is major contrast with the Scientific Revolution of Copernicus, Galileo

cf also
Dictionary of Scientific Biography
(ed. C.C. Gillispie)

Medieval Treatises often usual in the form of Questions interpolated in Commentaries on the works of Aristotle.
Position is adopted then attacked and final position is then defended (these are the authors own opinions)

Books on Medieval Mechanics

E.J. Dijksterhuis De Mechanisering v.d. Wereldbeeld (1950)

A. Crombie, Augustine to Galileo (2 vols.)
F. Grant, Robert Grosseteste and the origins of Experimental Science (1953)
Physical Science in the Middle Ages
(1971)

F. Grant Source Book in Medieval Science
1974.

P. Duhem Etudes sur L. de Vinci (1906-1913)
Le Système du Monde (1913-1959) 10 vol.
discussed the Paris 14th C. school
emphasized their influence on Galileo

Now revised response by
A. Koyre : Etudes Galiléennes
(1939)
a A. Maier : Die Vorläufer Galileis
im 14. Jahrhundert (1949).

Marshall Clagett The Science of Mechanics
in the Middle Ages
(1959)
with translations.

D. Lindberg (ed.) Science in the Middle Ages (1978)
15 essays on Medieval Mechanics
with many references

cf also F. Grant: Much Ado about

Nothing: Theories of Space and Vacuum from
the Middle Ages to the Scientific Revolution.
C.U.P. (1981)

A. Franklin The Principle of Inertia in the Middle Ages, 1976. (Am. J. Phys. 44 (1976) 529.) cp also

cf two articles:

F. Grant Isis, 55 (1964) 265

'Motion in the Void and the Principle of Inertia in the Middle Ages'.

E. Moody J. Hist. Ideas 12 (1951) 163, 375

'Galileo and Avempace: The dynamics of the Leaning Tower Experiment'.

Medieval Dynamics

Aristotle $V = k\, F/R$, $F > R$ assumed

Motion requires both forces, constant

John Philoponus (6th C. A.D.) and Avempace (12th C. A.D.) replaced with

$$V = k\,(F-R)$$

Hence motion in a vacuum became possible.

Thomas Bradwardine ~~$v = k \ln F/R$~~ ($F > R$?)

$$V = V_1 \log_a F/R$$

i.e. $\left(\frac{F_1}{R_1}\right)^{V_2/V_1} = \frac{F_2}{R_2}$

where $a = F_1/R_1$ $(F_1 > R_1)$

Note $V = 0$ for $F = R$ in Bradwardine's Law

The Concept of Impetus

John Philoponus departed the role of air in projectile motion — we cannot move stone by agitating air behind it — introduced an incorporeal motive force

developed by

Avicenna (Arabic = intellect or tendency)

led to work of (c. 1295 – c. 1358)

John Buridan introduced term impetus

~~Force~~ impetus = mass + vel.

But impetus is cause of motion not effect of motion, so it is not momentum

Buridan also explained accelerated motion of free fall by assuming acquisition of increments of impetus

gravity produces vel. + impetus

↳ more velocity

and so on

Buridan again uses infinite motion in void as argument against the view impetus is not dissipated (friction)

cf doctrine of transient impetus due to Nicholas Bonetus (died c. 1343)

Rational Kinematics (The Existence & Removal of Forces & Qualities)

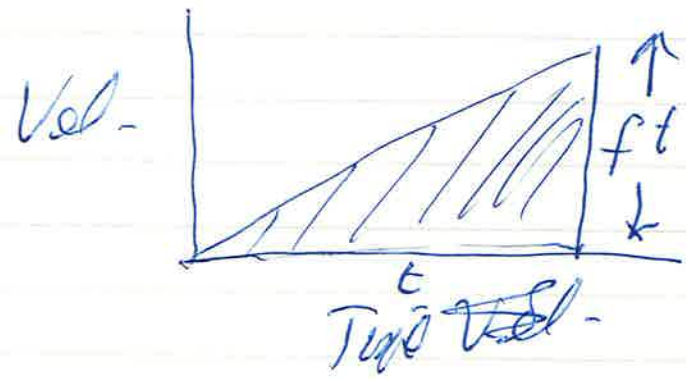
The Merton School.

William Heytesbury, John Dumbleton, Richard Swineshead

Thomas Bradwardine. 'Proportions of Motions' (active at Merton College 1328–1350)

Mean Speed Theorem

$$S \propto = \frac{1}{2} ft^2 = \underbrace{\frac{1}{2}(ft)}_{\text{mean speed}} \times t.$$



~~Vel.~~

S = area of Δ. $= \frac{1}{2}(ft) \cdot t$.

Also known by.

Nicole Oresme (c. 1320–1382)

'On the ~~Configurations~~ Configurations of Qualities'

Glossary of Astronomical Terms

Zenith — Pole of horizon system

Altitude and Azimuth (horizon system)

Declination · right ascension (equatorial system)

celestial latitude & longitude (ecliptic system)

ephemerides — elements of a planetary motion

apogee, perigee
farthest from earth, nearest to earth

motion { diurnal daily; annual yearly; secular slow or aperiodic

aphelion, perihelion
farthest from sun, nearest to sun.

apsis of orbit

line of apsides joins apogee & perigee ~~[illegible]~~

nodes intersection of orbit with ecliptic

syzygy object earth & sun in opposition or conjunction (i.e. in a st. line)

quadrature object at rt. angle to earth-sun line.

Ecliptic path of sun 23½ to equatorial plane

Zodiac belt in sky 18° wide about the ecliptic, divided into 12 houses or signs; path of the planets (wandering stars)

Books

J. L. E. Dreyer

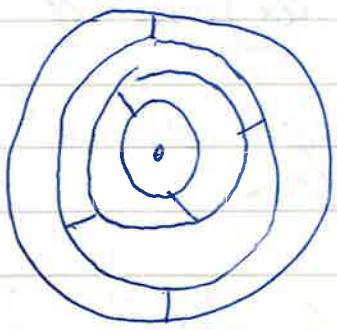
History of Astronomy from Thales to Kepler (1906)

R. Pannekoek: ~~A~~ History of Astronomy (1961)

Sir Thomas Heath - Aristarchus of Samos (1913)

O. Neugebauer (3 vols)
A History of Ancient Mathematical Astronomy (1975)

J. L. E. Dreyer Life of Tycho Brahe, 1890.



Aristotle

Greek Astronomy

~~Two~~ three main schools:

1) Homocentric — Earth-centred spheres.
{ Eudoxus (c. 408 – 355 B.C.)
{ Callippus (c. 330 B.C.)
{ Aristotle.

Difficulty: does not explain varying brightness of planets, size of moon etc., which suggests 'heavenly' objects at 'varying' distances from the earth.

2.) Heliocentric (9 bodies = earth, sun, moon, 5 planets, fixed stars as sphere) (note 10 = 1+2+3+4 and is a perfect no. for Pythagoreans)

Developed from theories that the earth moves

Philolaus (5th c. B.C. Pythagorean): earth and sun revolve round a central fire (also a counter earth) (10 bodies in all concentric) in 24 hrs for the earth.

Rides other side of earth from fire. Our side of earth always turned away from central fire.

Heracleides of Pontus (c. 388 – 315 B.C.)

Earth rotates. also Mercury, Venus go round 'sun', explain why these planets always 'close to the sun in the sky', sun goes round the earth.)

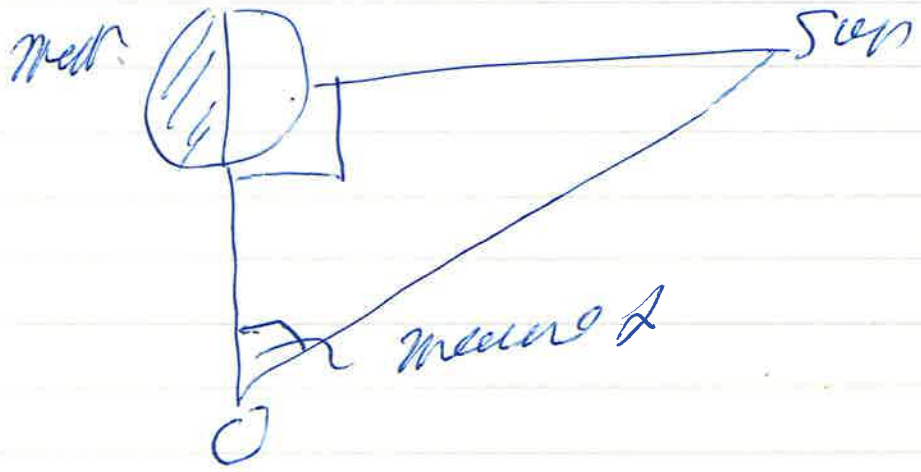
ch adv Apollonius (c. 220 B.C.)
Hipparchus (c. 190 – 120 Bc.)

who developed epicycle theories
and discovered the
precession of the equinoxes
(Hipparchus)

Aristarchus of Samos (c. 310–230 B.C.)

in the 'Ancient Copernicus')
earth rotates on axis, and
goes round the sun.)

Main difficulty in theory of planetary motion, underlying retrograde motion, and varying brightness of the planets
Aristarchus estimated ratio distance E
sun : moon thus



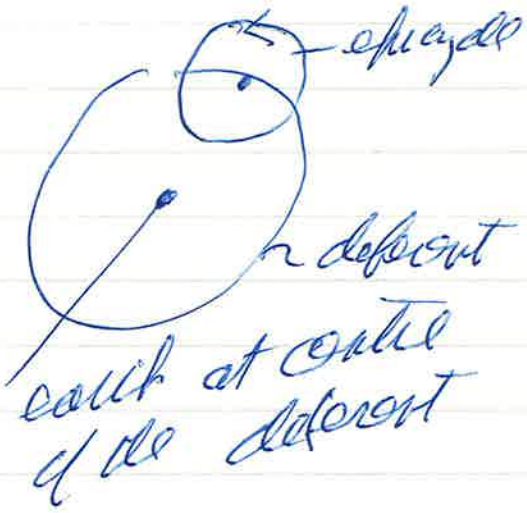
$\frac{OM}{OS} = \cos\alpha$, But α is near to 90°
- difficult to measure very accurately.

Aristarchus estimated $\alpha = 87°$ (real 89°52') - Sun/moon = 18 (real 390).

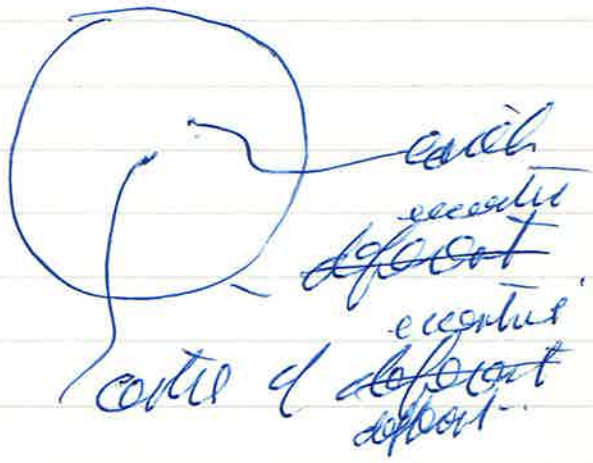
3. Epicycle theories explain distinct
of planetary motion, including retrograde
motion, and varying brightness
of the planets
culmination in work of
Claudius Ptolemy (2nd c. A.D.)
who wrote the Almagest

Ptolemy's system uses 3 main devices

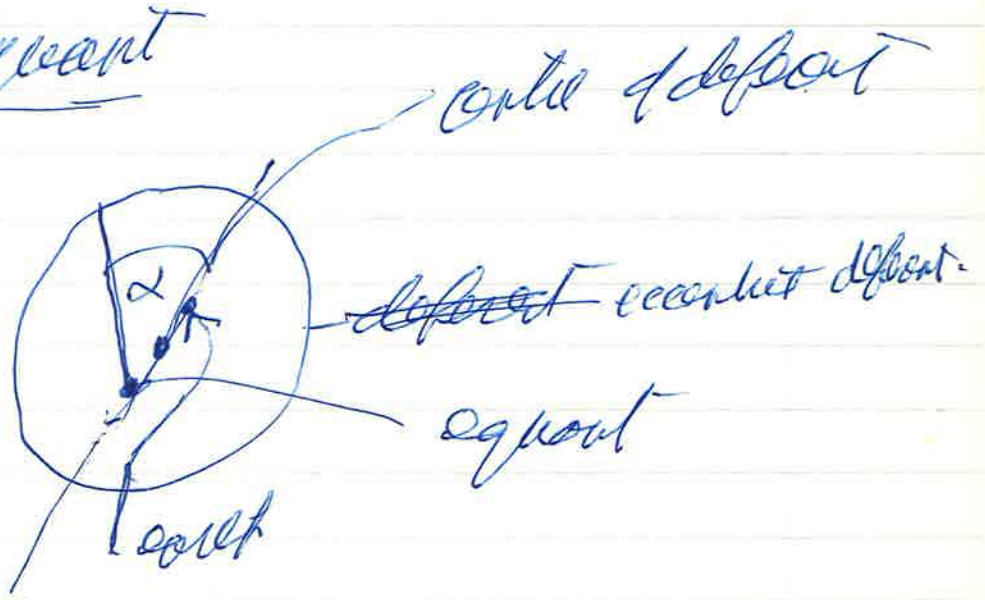
a) The epicycle



b) The eccentric ~~deferent~~ deferent



c) The equant



It is uniform

The devices can be combined in various complicated ways

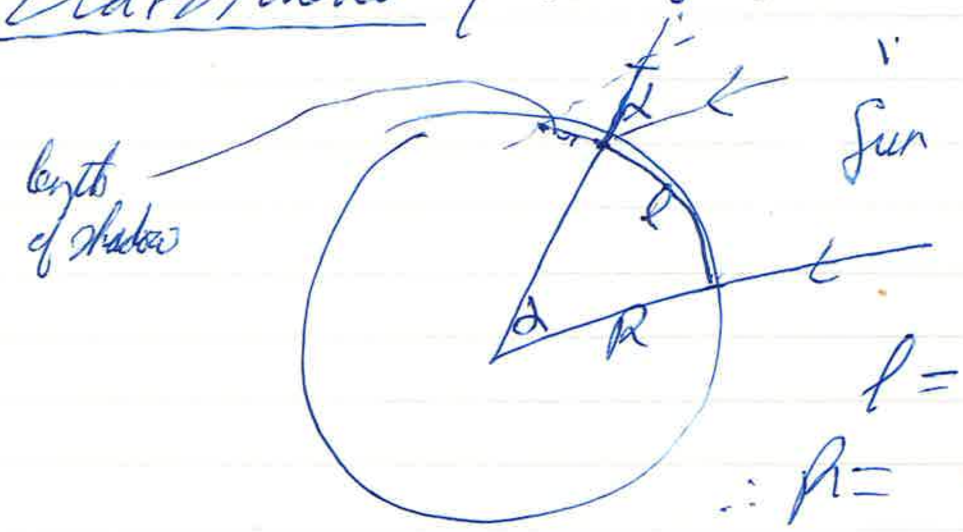
The figure of the earth

Aristotle and most Greek astronomers accepted that the earth was a sphere.

Reasons:
- horizon
- shape of earth's shadow on the moon
- shape of moon and sun
- sphere 'perfect figure'.

Estimate of size of the earth by

Eratosthenes (c. 276–194 B.C.)



$$l = R\alpha$$

$$\therefore R = l/\alpha.$$

N.B. In the Middle Ages everyone accepted earth was round.
— Argument of Columbus was 'how large is the earth' i.e. how long to sail to the Indies by the Westward route.

Medieval astronomy.

followed Ptolemy.

15 century Georg Peuerbach and his student
Johannes Müller (Regiomontanus)

based their work directly on the
Almagest -

But in 14th century idea that
earth moves was mooted,
particularly by (rotation of earth without
Buridan and by dept of dominance)
Nicole Oresme (c.1320-1382)

- deals with the Tower argument
by version of Galilean Relativity:
air carried round by ~~air~~ earth
objects share motion of the air
Notion of (circular) inertia
not really present until Galileo.

Also plurality of worlds was argued
for as possible by Oresme, Buridan
& Albert of Saxony

and an infinite universe by
Nicholas of Cusa (Cusanus)
- forerunner of Thomas Digges and Giordano
Bruno in the 16th C.

Books on the Scientific Revolution:

* A. C. Debus: Man, Nature and Renaissance (1978)

F. A. Burtt: The Metaphysical Foundations of Modern Physical Science (1932) rev. ed.

H. Butterfield The Origins of Modern Science (1952)

Marie Boas The Scientific Renaissance (1450–1650) (1962)

* R. S. Westfall The Construction of Modern Science. (1971) many pbk ed.

A. R. Hall The Scientific Revolution (1500–1800) (1954) 2nd ed 1962.

→ The Revolution in Science 1500–1750 (1983)

A. R. Hall From Galileo to Newton 1630–1720 (1963)

paved to Marie Boas' end

The Renaissance

In Art, literature the R. dates from 13th Century.

Rediscovery of Greek texts and learning to read Greek itself.

↳ Respect for the ancients

But 3 other factors:

1) 16th C. translation & appreciation of Archimedes led to example of how to do mathematical physics

Also revival of Neo-Platonism & number-mysticism clearly seen as influence in Kepler.

2.) A new sense of using reason and observation to get at the truth of reality behind the appearances — rejection of 14th C. strict empiricism made second possible again.

3.) Respect for texts more ancient than the Greeks
— Hermes (Trismegistus) – legendary Egyptian alchemist, the Hermetic literature
↳ Rosicrucians, the study of alchemy

— the rediscovery of an ancient wisdom lost even to the Greeks

"Scientific" these two themes: reason, mathematics & observation

"Mystical" and Mysticism, Natural Magic, Alchemy, etc.

on the other are most characteristic of the period 1450–1650

In some cases, e.g. Newton the two interests are indeed combined.

The first theme led to modern science; second petered out ~~towards~~ in the 18th Century.

Ex. of Mystical approach

John Dee
Robert Fludd
Paracelsus. (Philippus Aureolus Bombastus von Hohenheim).

Books

A. Koestler — The Sleepwalkers
deals with Copernicus, Kepler (the hero) & Galileo – rather unfair to Galileo

T. Kuhn — The Copernican Revolution

A. Armitage — Copernicus

Translations of De Revolutionibus:

Duncan (colloquial)
Rosen (1978) more scholarly.

Good F. Rosen: 3 Copernican Treatises:

The { Commentariolus
Letter against Werner
Narratio Prima

support of ancient observations which had been challenged by Werner

Nicolaus Copernicus (Niklas Koppernigk) (1473 – 1543)

born in Thorn in Poland

Studied in Italy at Bologna, Padua, Ferara

returned as Catholic Canon in 1506
to ~~an~~ Ermland. (Canon of Frauenburg Cathedral)

His Heliocentric System was not published
until the year of his death

Preliminary manuscript: De Commentariolus
1517 described system in broad outline.

Persuaded to Publish De Revolutionibus
Orbium Coelestium
by his disciple Geog. Joachim Rheticus, who came
to study under him in 1539.

Rheticus published De Narratio Prima in 1540
, again an introductory account of
the complete plan
Rheticus returned to Nuremberg
to supervise the publication of
de Revolutionibus but was called
to a chair in Leipzig and the final editor
was Andreas Osiander who contributed
a former preface, claiming that
Copernicus' system was just another
way of saving the phenomena not
to be taken in a realistic sense

Summary of De Revolutionibus (6 Books)

Osiander's Introduction:
'Nor is it necessary that these hypotheses should be true, nor indeed even probable, but it is sufficient if they merely produce calculations which agree with the observations'.

Preface: To his Holiness Pope Paul III.

C says he will be 'hooted off the stage' for his opinions (explains his delay in publication?)

C says he was influenced by the disagreements among the ancients, homocentric, epicycles systems etc — then refers to 'Philolaus, Heraclides and Ecphantus [who believed the earth moves. — (quote from Plutarch)

Book 1

ch 1. Universe is spherical — perfect & most capacious shape

2 Earth is spherical: Brings phenomena rising & setting of stars, varies with latitude etc.

3. Has water upon earth — explains dry land! earth less likely to fly apart says Kuhn.

4 Motion of heavenly bodies is uniform, circular & perpetual, or compounded of such motions — rejection of the equant.

5. Circular motion also proper to the earth rotation + planetary motion

#6 The immensity of the heavens as compared with the size of the earth.
— parallax argument — not used.
— absurd that stars revolve every 24 hours.
(says horizon bisects celestial sphere — ... argument — ...)

7. Why the ancients said the earth was at rest.

a) earth falls to the centre because it is heavy.
(b) — former argument.
(c) [Natural and] etc → (motion of clouds) its example actually used by C.
(d) earth would fly asunder
8. Refutation of these arguments — i.e. earth may rotate circular motion is natural, air also rotates
Merely think that they are at rest.
Natural motion of earth will not disintegrate it — what about stars if they revolve would not whole universe fly apart?
9. On several motions of the earth, i.e. is it a planet? where is the centre of the universe? The Sun

C says gravity assembles everything into globular shape — planets as well as earth (not only related planets ...?)

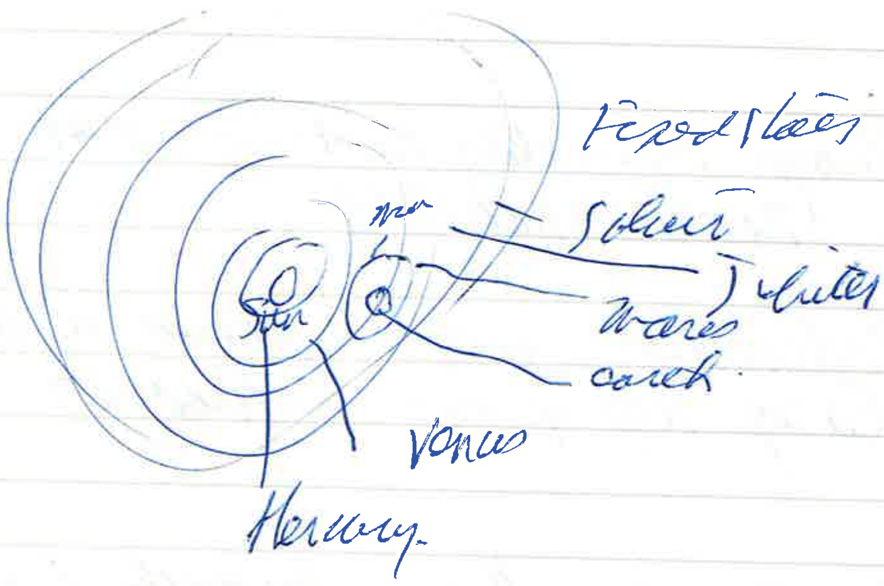
"I myself consider gravity is merely a certain natural inclination with which parts are imbued by the architect of all things for gathering themselves into unity and wholeness by assembling into the form of a globe. They say it is believable that the sun, moon and other luminaries among the wandering stars have this tendency also so that by its agency they retain the rounded shape in which they reveal themselves but nevertheless go round their orbits in various ways"

Nos planetes attribuée to the Sun as Rh 10

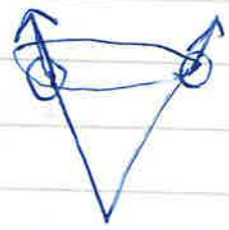
"In the middle of all is the seat of the Sun. For who in this most beautiful temple would put the lamp in any other or better place than to the one from which it can illuminate everything at the same time. Aptly indeed is he named the lantern of the Universe by Hermes the mind, by others the ruler. Thus enthroned the Sun as if seated on a royal throne governs his family of Stars as they circle round him."

But in the detailed theory we receive reports to men can not readily at the center.

Ch. 10 The order of the heavenly spheres.



Furthest planets have longest periods



2nd mean of annual motion of earth.

11. The Triple motion of the earth
diurnal, annual and secular (non uniform precession of the equinoxes – but mainly to explain constant direction of earth's axis)

12. 13, 14 Trigonometry of plane & spherical triangles.
↑ circle theorems

Bk 4 is lunar theory
5 Anomaly in longitude } planetary motion.
6 — in latitude }

Bk 3 the precession of the equinoxes (earth's 3rd motion) & the annual motion

Bk. 2. General mathematical scheme of motion of the earth (diurnal only) ~~annual~~.

Translations E. Rosen 1978 (more scholarly)
A.M. Duncan 1976 – Colloquial

Biography JLE Dreyer : Tycho Brahe (1890).

Major observatory built on Hveen – named Uraniborg.

Instrumental errors reduced by very large size of his instruments.

In 1588 new King of Denmark (Christian IV) wearied of Tycho's arrogance and expenditure on the upkeep of Uraniborg,

Tycho travelled with his instruments & students looking for a new home and finally settled in Prague.

N.B. In Tychonic system Earth's orbit intersects Mercury, Venus and Mars – crystalline spheres not possible.

* Cf also Kepler 1900 'Apologia Pro Tychone Contra Ursum' – Translated in new scholarly edition of N. Jardine (1984) entitled "The Birth of History and Philosophy of Science" : Kepler's Defence of Tycho against Ursus

(Heavenly Castle)

Tycho Brahe (1546–1601) Danish Astronomer
left Denmark (Ven, Uraniborg) in 1597 → Prague as Imperial Mathematician in 1599
Carried naked-eye astronomy to its highest possible point of accuracy

In 1572 Tycho observed a new star
(a supernova)

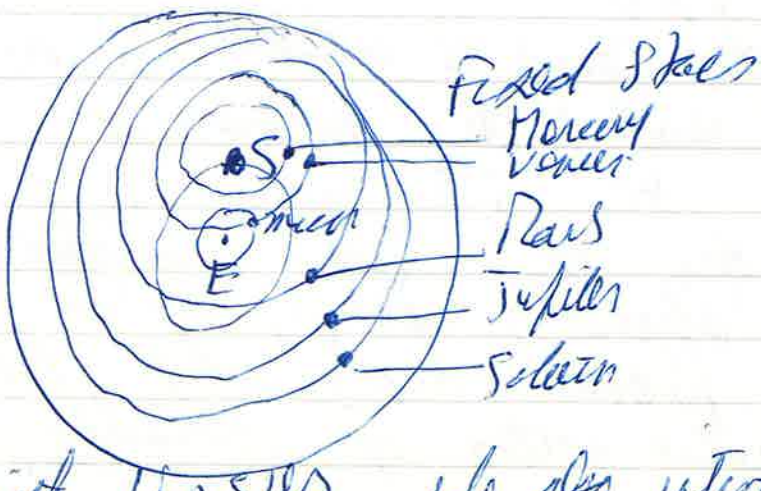
In 1577 Tycho observed the absence of parallax* of a comet and deduced that comets were not sublunary phenomena, but were transient planetary phenomena → change could occur in Heaven and crystalline spheres don't exist as comets would have to crash through them.

* Parallax due to earth surface not at centre of rotation

The Tychonic System (1588)

5 planets revolve round the Sun.
But Sun and Moon revolve round the earth which is stationary at the centre of the sphere of fixed stars

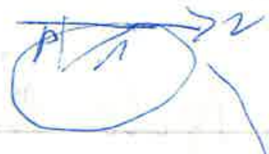
explains why no parallax found for the stars



* Argument with Ursus who also introduced this debate in the same year (probably not a case of plagiarism)

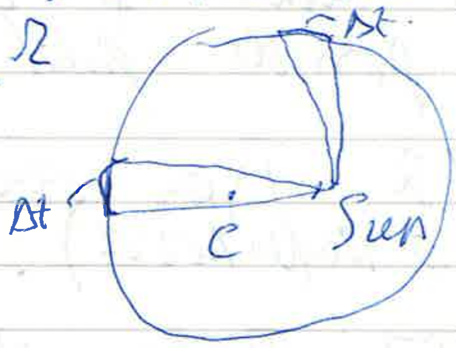
Discovery of 2nd Law

[actually $v \propto 1/p$]



$F \propto 1/r$ ∴ $v \propto F \propto 1/r$

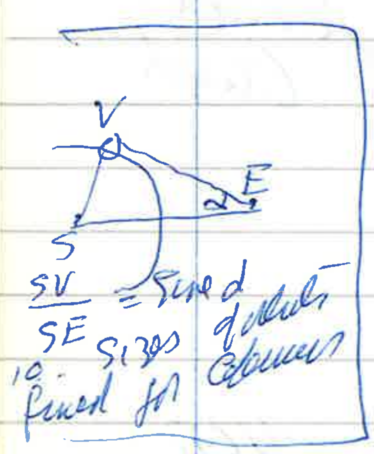
∴ $\Delta t \propto r$

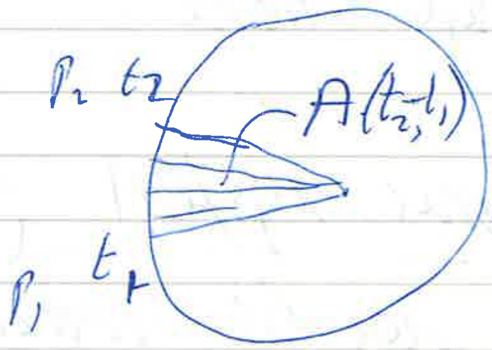


only true at aphelion, perihelion !

Then $\text{Area}_{(t_2,t_1)} \propto \sum_{P_1}^{P_2} r$ (!)

$\propto \sum_{P_1}^{P_2} \Delta t = t_2 - t_1$





ie. Area ∝ Time.

Note if ~~Δt ∝ r~~ $v \propto 1/r$ then $T = \frac{2\pi r}{v} \propto r^2 = kr^2$

But this cannot be extended to all planets since the constant k depends on the distance ie. 3rd Law $T \propto R^{3/2}$

Note also for rigid rotation of sun with fixed 'spokes') carrying round the planets 1 = const, so planets must slip backwards in magnetic vortex of rotating sun. (Gatsfield's law = 1621)

Kepler also produced work on optics & developed the theory of the telescope being used by Galileo (Dioptrice 1611)

Johannes Kepler (1571 – 1630) b. at Würtemberg

Studied under Michael Maestlin (1550–1631) at Tübingen (Ptolemaic theory but Copernican also discussed). — K. became an ardent Copernican and believed by Maestlin

Mysterium Cosmographicum (1596)
K. sent copies to Tycho & to Galileo.
(Affirmed in the Copernican system, although not with Ptolemaic)
Distances of planets given by separation of the 5 regular solids: cube, tetrahedron, octahedron, dodecahedron and icosahedron

Kepler worked at Graz (1594–1600) as 'Provincial Mathematician' of Styria
but K. joined Tycho as his assistant in Prague in 1600; → Imperial Mathematician on Tycho's death in 1601 → Linz in 1612.
K. postulated Anima Motrix (cf Gilbert's magnetism) emanating from Sun and moving the planets, inverse distance law in the plane of the ecliptic, but acting tangentially.

Astronomia Nova (1609) 2nd, 1st law of planetary motion stated, 1st law based on careful study of orbit of Mars based on Tycho's observations (discrepancy of 8' of arc)

Harmonices Mundi (1619) 3rd law stated
Mystical study of musical harmonies of motions of the planets → $T^2 \propto R^3$

Completed Tycho's planetary tables (the Rudolphine Tables) in 1627.

Standard biography of Kepler is
by Max Caspar (1948) Eng. trans. 1959.

See also
C. Hellen - Brit. J. Hist. Sci. 24 (1958) 340-351
"Johannes Kepler's Universe: Its Physics
and Metaphysics"
reprinted in "Thematic Origins of
Scientific Thought" (1973)
Kepler to Einstein.

Principal features of Kepler's approach
(cf Dijksterhuis p. 322)

1.) Rejection of arguments based on tradition, authority

2.) Independence of Scientific enquiry from philosophy and theology

3.) Constant application of mathematical modes of thought in framing hypotheses

4.) Rigorous testing of geometrical models against accepted empirical data.

Books on Galileo

A. Koyré : Galilean Studies (1978 Trs)
G. on platonism
M. Clavelin : The Natural Philosophy of Galileo
(1974 Trs.)
F. McMullin : Galileo, Man of Science (1967)
S. Drake : Galileo (1980)
and Galileo at work (1978)
D. Shapere : Galileo : A Philosophical Study (1974)
G. de Santillana : The Crime of Galileo
(1955)

A. Koestler : The Sleepwalkers, part III.

W. R. Shea : Galileo's Intellectual Revolution
(1972)

M Finocchiaro : Galileo & the art of Reasoning
(Analysis of Dialogo) 1980

R. Butts & J. Pitt (eds) New Perspectives on
Galileo (1978)

Galileo's works

S. Drake : Discoveries & Opinions of Galileo
(Starry Messenger, letters on Sunspots, Letter to Christina
, the Assayer), 1957.

Dialogue Concerning the Two Chief World Systems : Ptolemaic, Copernican
Trn. Stillman Drake. 1953, rev. ed. 1967 (Also Salusbury
1661 ← Translation revised by de Santillana → 1953)
Dialogues Concerning Two New Sciences
Trn. Crew & de Salvio 1914 and S. Drake 1974
(Discourse & Demonstrations Concerning Two New Sciences)

Galileo Galilei (1564 – 1642)

Son of a Musician (Vincenzio Galilei)
Born at Pisa, enrolled as a Medical student at University of Pisa – left without a degree and captured early Greek works by Euclid and Archimedes.

1589 Chair of Mathematics at Pisa
– Early treatise on Motion (de Motu) critical of Aristotle, claimed equal time of fall for bodies of different weights – apocryphal experiment of dropping weights from Leaning Tower of Pisa

1592 Chair of Math at Padua (Venice) (more freedom than Pisa post)

Here he discovered isochronism property of the Pendulum, and devised device of bodies along arcs, studying acceleration.

1610 Pub Starry Messenger:
Mountains on the moon,
Stars in Milky Way, moons of Jupiter (Medicean stars)

Galileo developed the telescope (discovered in Holland) 1609 – 1610. — After Sept. published he discovered phases of Venus.

1610 As a result of fame from Sidereus Nuncius G. resigned his chair at Padua and returned to Florence as Mathematician & Philosopher to Grand Duke of Tuscany (Medici)

1613 Letters on Sunspots
attack on Scheiner for priority in observing sunspots
S. claimed they were planets moving across the face of the sun.
G. said they were 'defects' on the surface of the sun which were moved by the Sun's rotation. Also explicit support for Copernican system.
1615 Letter to Christina on role of theology in Science.

1616 Pope Paul V made edict that G could not defend the Copernican views.

1618 Grassi wrote book on Comets attacked by Galileo

1619 Grassi published The Astronomical and Philosophical Balance - attacking Galileo (under pseudonym Lotario Sarsi)
1623 G. replied with Il Saggiatore (The Assayer)
(i.e. the 'finer' balance)

G thought comets were optical illusions
drew distinction between primary, second qualities
— very polemical work.

1632 Dialogo published
upset Pope Urban VIII (Barberini)
who was friendly to Galileo.
Simplicio = Pope ?

1633 Trial of Galileo by inquisition
G. retracts.
Book placed on index
no further publications allowed.
G. sentenced to life imprisonment
— commuted to house arrest.
"Eppur si muove" probably apocryphal

1638 Discorsi published in Holland
(G. was by then blind)

Day 1 Problem of cohesion, continuity, infinity,
  2 nature of sound, speed of light etc
  — many diversions from main topic of strength of materials
  [margin: related to vacuum in cohesion → Discourse of Dissolution Motion]
2 strength of materials bending of beams, scale invariance queried!

3. accelerated motion $s = \frac{1}{2} g t^2$
inclined planes, chords ? arcs of circle etc

4. Parabolic motion of projectiles
(Composition of motions)

Projected 5th day dealing with theory of impact

shouts for G. — Simone sense — Aristotelean 4
(arrows pointing to Salviati, Sagredo, Simplicio)

<u>Dialogo</u> Salviati, Sagredo, Simplicio

Day 1. Unity of terrestrial and heavenly phenomena.

appearance of moon etc

2. argument for rotation of earth.
relativity of motion & inertia

3. argument for annual motion of earth
– simplicity of explaining retrograde motion of planets, phases of venus, etc.

Also motion of sunspots due to inclination of sun's axis to ecliptic.

4. Theory of Tides – main argument for motion of the earth for G.
<u>not</u> due to attraction of moon but due to acc. & decel. in motion of earth as its rotational motion adds to & subtracts from its orbital motion.
<u>But</u> only 1 tide per day?

Also contradicts (in fact?) G's argument that motion could be detected.

Two main events in 17th C. Science.

1.) Mathematization of Nature
   - not taken for explanations
   - culminates in Newton's Principia (1687)

2.) Mechanical philosophy, taken for
   mechanical (i.e. motion; impact)
   explanations.

Books

R.S. Westfall: Force in Newton's Physics,
   The Science of Dynamics in the 17th C. (1971)

R.S. Westfall: The Construction of Modern
   Science: Mechanisms & Mechanics 1971.

S. Gaukroger (ed.) Descartes: Philosophy,
   Mathematics & Physics (1980)

3 Types of matter
   primary or subtle matter
   celestial matter (= secondary matter) Stars & Sun
   Terrestrial matter. (earth & planets)

} termed "primary matter"

Rene Descartes (1596–1650) born in Brittany, lived in Holland 1629–1649, died in Sweden. (introduction to Queen Christina)

Discourse on Method (1637) to which are attached Géométrie ~~Geometry~~, La Dioptrique and les ~~Meteor~~ Météores (theory of rainbow)

Géométrie ← English translation in 1925.

(Discourse on the method of Rightly Conducting the Reason & Seeking for Truth in the Sciences)

Meditations on the First Philosophy in which the Existence of God and the Distinction between Mind & Body are demonstrated ~~(164~~ (1642)

The Principles of Philosophy 1644.

D's treatise Le Monde, published posthumously in 1664

Here D described his Mechanical philosophy of world governed by matter (extension) & motion. Afraid to publish because of G's trial.

Main contributions of Descartes

1.) Law of refraction

2.) Law of inertia inverted

3.) mv conserved (wrong)

4.) Discussion of centrifugal force ⟹ speculation

5.) Laws of impact (wrong in most cases) e.g. small body cannot budge a larger body.
 └ corrected by Huygens.

See J. Losee

A Historical Introduction to the Philosophy of Science (1972)

Bacon's 3 analogies

The Empiricist = The Ant.
Rationalist (Philosophers) = Spider who spun webs from their own bodies
True Scientist = The Bee who extracts matter from flowers and transforms it into honey useful for all.

Bacon was very influential in 17th half of 18th C and of the Royal Society (founded in 1660) was strongly Baconian in outlook.

Francis Bacon (1561 – 1626)

was knighted in 1603, Lord chancellor in 1618, Baron Verulam in 1618, Viscount St Albans in 1621. Bodley guilty to taking bribes (never influenced his judgements!) – Banished from public life.

The Great Instauration

1. The Advancement of Learning (1605) – Classified the sciences
2. Novum organum (1620) (new instrument logic)

New Atlantis (1627) – Imagined Utopian Bacon-based society.

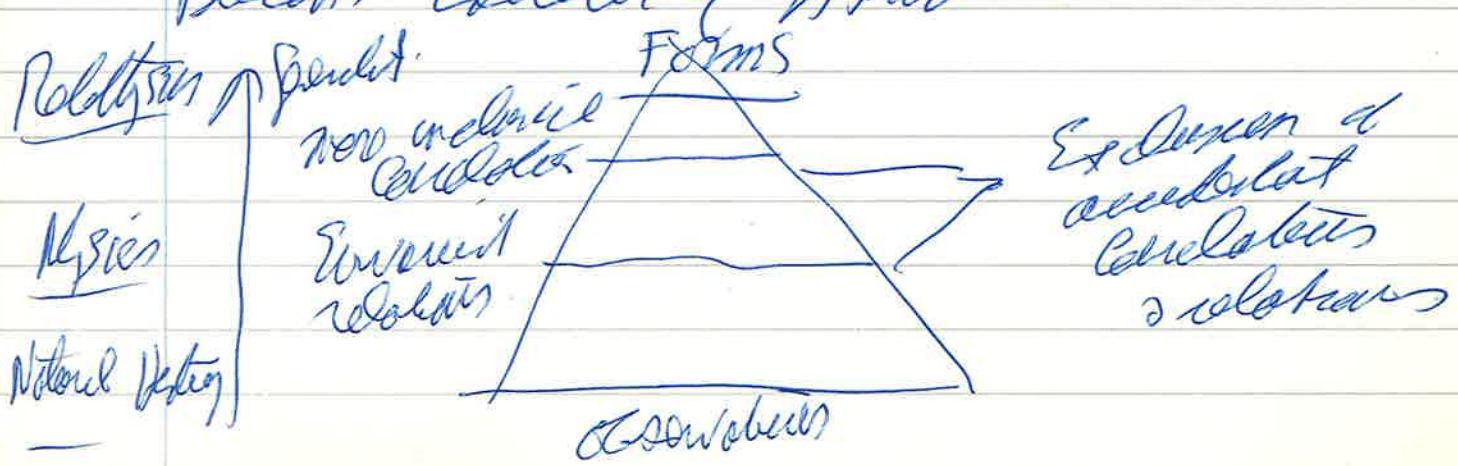
Idols of the Tribe Too hasty generalizations

Cave projected personal fancies, education

Market Place Vulgar usage of words embodies formation of false scientific concepts

Theatre Dogmas of philosophical schools and misleading laws of demonstration

Bacon's Ladder of Axioms



not equal to Bacon, ←

eg Grosseteste, Witelo, Scotus,
Roger Bacon.

eg Tidal Theory: T_1: Solid's model
T_2: Rising & falling of sea.

e = evidence of tidal ebb tides
across ocean.

Tables of Presence
Absence
Degrees

Prerogative Instances of special importance
e.g. Instances of the Finger Post.

+ $T_1 \rightarrow e$, $T_2 \rightarrow 2e$ } Crucial experiments

Search for Forms
Ex Form of heat is motion of expansion
↓
Aristotelian vestiges here.

Science as a mechanical aid
to discovery — avoid pers. distortions
to the metaphysical truths of the forms.

Purpose of science is not knowledge
for its own sake but for control
over Nature & improvement of Society
— Co-operative scientific research
urged in New Atlantis

New Physiology of the Magnet and Magnetick Bodies, and of the Big Magnet, the Earth.

Magnetism due to accent specially but electrical attraction due to effluvium

Gilbert's work on the double vortex Hermeticism, Natural Magic on the one hand and Empirical Science on the other

William Gilbert (1544–1603)

published De Magnete (1600)
— Magnetic influence was an occult property (action at a distance due to effluvium)

Pierre Gassendi (1592–1655) revived
Copernican Heliocentrism — more recent
to Epicureanism.

· Syntagma Philosophicum (1658)

Evangelista Torricelli (1608–1647) G's disciple

Blaise Pascal (1623–1662)

Francis Bacon (1561–1626)

De Great Instauration

Novum Organum (1620)

Christian Huygens (1629–1695)

Son of Constantijn H., friend of Descartes

Works: De Motu Corporum ex percussione (1656)
(On the motion of bodies in percussion)

Horologium Oscillatorium 1673, invented the pendulum clock in 1657 & described in Horologium (1658)

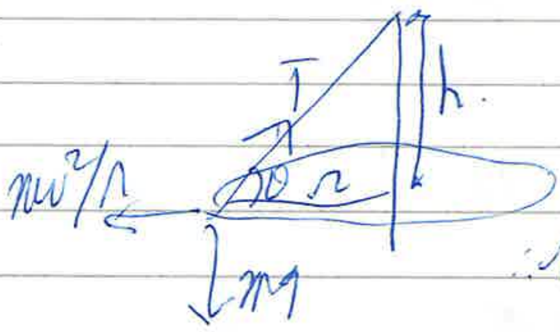
Treatise on light 1690

~~expanded in~~ De Vi Centrifuga (1659)

Huygens derived $F = mv^2/r$
→ applied to problem of why bodies do not get thrown off rotating earth and coined term centrifugal force.

(margin: removed major objection to a moving earth!)

Analyzed conical pendulum as a 'balance' between centrifugal force and tension in the string.



$T\cos\theta = mv^2/r = mr\omega^2$
$T\sin\theta = mg$

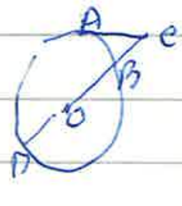
$\therefore r \cdot m\omega^2 / g = mg \cot\theta$

$\therefore \omega = \sqrt{\frac{g}{r\tan\theta}} = \sqrt{\frac{g}{h}}$

period $= \frac{2\pi}{\omega} = 2\pi\sqrt{h/g}$

as $\theta \to 90^0$ H. says conical pendulum → simple pendulum with period $2\pi\sqrt{l/g}$.

Centrifugal force



note $CD \cdot BC = AC^2$ or $2r \cdot BC = (vt)^2$

$\therefore BC = \frac{1}{2} \cdot \frac{v^2}{r} \cdot t^2$

centripetal acceleration

cf modern Treatment

$\Delta v = v\,\delta\theta$

$acc = \frac{\Delta v}{\delta t} = \frac{v\,\delta\theta}{\delta s / v} = \frac{v^2}{\delta s/\delta\theta} = v^2/r$

Christiaan Huygens (1629–1695) (believed in the vacuum contra Descartes)

1.) Recognized momentum is a vector.

2.) Correct laws of impact
($\frac{1}{2}mv^2$ conserved as well as mv for elastic impact)

obtained by many reference frames.

relative to the 'symmetric' center-of-mass collision →← ⇒

3.) Motion of a pendulum; centrifugal force, conical pendulum, compound pendulum.
Discovered cycloidal pendulum as truly isochronous.

– Continued Archimedean approach to collision etc

– against any action-at-a-distance

no concept of 'force'.

4.) Developed wave theory of light
– pulses rather than periodic motions.

– no explanation of rectilinear propagation or of ~~double refraction~~ polarization

– The Huygens construction

but complete account is given of double refraction

1686 ' A Brief Demonstration of a Memorable Error of Descartes' $mv \to mv^2$.

1692 Essay de Dynamique

1695 Specimen Dynamicum (article in Acta Eruditorum)

Gottfried Wilhelm Leibniz (1646–1716)
chief Logician - Mathematician;

b. in Leipzig, visited Paris where he came under influence of Huygens, became Librarian to the Duke of Brunswick at Hanover from 1676 – death – worked on historical genealogy (visited England in 1673) Main work to Hanover at end of life

Contributed to a) Philosophy
b) Mathematics – the Calculus – priority dispute with Newton
c) Dynamics.

Leibnizian Dynamics

Vis Viva mv^2 is measure of

Every force — what a moving particle can do (rather than what is done to it.

ie. to what height it can elevate a body.

cf Vis Mortua dead force or conservation, but sometimes L. seems to be clear to regarding Vis Mortua as potential energy.

Leibniz thinks Vis Viva is conserved — transferred to moved particles or a body, but L. does not say this is apparent or true.

Also when a ball bounces it reaches to same height — its vis viva is kept totally

(= vis viva of the aether?).

or Vis Mortua). These passages about Vis Mortua are rather unclear in Leibniz.
Leibniz never developed a fully worked out dynamics along the lines of Newton.

(mv^2 or mv as measure of force.)

<u>Vis-Viva Controversy</u> lingered on to middle of 18th C. — then recognized as a verbal dispute

$$\frac{1}{2}mv^2 = \int F ds \quad \text{work}$$

$$mv = \int F dt \quad \text{impulse.}$$

where F is Newtonian 'force'.

Leibniz analysed impact in terms of vis viva of parts of the bodies — elastic deformation of bodies part, i.e. <u>dynamical</u> approach as compared with Huygens <u>kinematical</u> approach to impact — also could ~~explain~~ <u>inelastic</u> impact.
Also Matter is not inert but consists of centres of activity (Monads) — really controverting and the medieval philosophy.

But <u>note</u> Monads are windowless — they do not interact — preestablished harmony of different 'perspectives' on reality i.e. each monad mirrors the universe. It predicates take account of what all the other monads are doing.

H. Brougham & F.S. Dodd
'Analytical View of Sir I. Newton's Principia' (1855) is a useful explanatory work.

Books on Newton

Never at Rest, A Biography of Isaac Newton
R.S. Westfall (1980)

(Previous biographies by Brewster (1855) & More (1934))

F. Manuel Portrait of Isaac Newton
— Psychoanalysis of Newton

R. Hall Philosophers at War (1980)
(Deputy not Leibniz)

R. Westfall Force in Newton's Physics 1971

J. Herivel The Background to Newton's Principia (1965)

I.B. Cohen Introduction to Newton's Principia (1971)

The Correspondence of Isaac Newton
7 vols. (1959–1977)

The Mathematical Papers of Isaac Newton
8 vols. ed. D.T. Whiteside (1967–1980)

Standard Cohen ed. of Principia (1687) Cohen & Koyré
(2nd. 1972)

I.B. Cohen Franklin & Newton (1956)

A.R. & M.B. Hall Unpublished Scientific Papers of Isaac Newton (1962)

I.B. The Newtonian Revolution (1980)

A. Koyré Newtonian Studies (1965)

Newton, Sir Isaac (1642–1727)

– never married

b. Woolsthorpe, Lincs; youthful interest in mechanical contrivances, fairy lights (carrying lanterns) later well proved by a model clock.

Trinity College Cambridge 1661, graduated BA in 1665.

1665–1666 Cambridge closed because of plague – annus mirabilis for Newton's work on Woolsthorpe on mathematics, optics, celestial mechanics

"I was in the prime of my age for invention & minded Mathematics & Philosophy more than at any time since"

Episode of falling apple.

1669 appointed Lucasian Prof. of Mathematics (Barrow resigned to make way for Newton).

1672 Made FRS.

1693 breakdown (fire destroyed work on optics (1692))

1696 left Cambridge to become Warden of the Mint (actually swapped his Cambridge chair in 1701)

Master of Mint 1700

1703 President of the Royal Society (until his death)

1705 Knighted

Quarrel with Leibniz (Newton's dispute over the calculus, (via Keill) – Commercium Epistolicum to report & PS on the dispute (actually by Newton))

Treatises on the Calculus

De Analysi — 1669 (published 1711)
(supposedly read by Leibniz)

Methodus Fluxionum et Serierum Infinitarum
— 1671 (published 1736)

Tractatus de Quadratura Curvarum
1676 (published in 1704)

Leibniz first published work on the calculus in 1684.

Certain Philosophical Questions:
Newton's Trinity Notebook
ed. J.E. McGuire and M. Tammy (1983)

The Optical Papers of Isaac Newton
Vol. 1: The Optical Lectures, 1670–1672
ed. A.E. Shapiro (1984)

Also dispute on philosophy & theology in relation to Science (via Clarke).

Major areas of interest

1.) Mathematics

2.) Mechanics & Astronomy

3.) Optics

4.) Alchemy, prophecy, chronology of the Ancient Kingdoms

5.) Scientific method.

Newton's major innovation was introduction of force into the ontology of physics

Action-at-a-distance rejected by Cartesian mechanical philosophers.

The Early Newton was more Cartesian. He believed in the aether to explain reflection & refraction of light, & colours of thin plates.

cp. "An Hypothesis explaining the Properties of light" - usually referred to as "Hypothesis of Light" — 1675.

— began to introduce 'sociability' i.e. forces between particles of the aire of aether c. 1674.

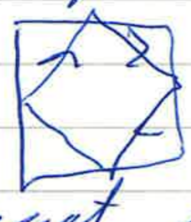
II Newton theory of colours was submitted to the R.S. in 1672
- provoked much criticism, especially from Robert Hooke
- light was modified by the prism, not split.
- maybe reason why Newton was loath to publish for dislike of criticism.

Force explicitly occurs in Principia (1687) but in the General Scholium to the 2nd ed. Newton gives some ground to the Cartesians in the jealous force by referring to a possible aetherial mechanism for gravity.
But in query 31 of second English ed. of Opticks (1717) Newton explicitly recognizes action at-distance in a wide variety of phenomena.
(Part of Queries 17-24 2nd English ed. of Opticks)

Newton's Works

1.) Questiones quaedam Philosophicae c. 1664.
~~[illegible]~~
45 headings covering most of his later interests and achievements in science
– organization of points of his readings on matter, place, time, motion, light, colours fluidity etc.

In 1665-1666 Newton (1) invented the calculus (2) discovered the Binomial theorem (3) did his experiments with the prismatic spectrum # (4) calculated centrifugal force by repeated impact from walls of a polygon in limit as it → circle.



(5) 'apple incident' led (?) to speculation on force of gravity extending to moon.

From Kepler's 3rd Law $T^2 \propto R^3$ *

∴ velocity in orbit $= \frac{2\pi R}{T} \propto \frac{R}{T}$

∴ centrifugal force $\propto \frac{v^2}{R} \propto \left(\frac{R}{T}\right)^2 \frac{1}{R} = \frac{R}{T^2} \propto \frac{1}{R^2}$

from *

* other forces than gravity might be acting – a view held by Newton apparently for a number of years.

So centrifugal ~~tend~~ force on planets ∝ $1/R^2$
If this is balanced by a ~~centrif~~ centripetal force of gravity ⇒ inverse sq. law for gravity.

Newton applied this to the case of the moon.

From period & distance of the moon he ~~estimated to~~ calculated ~~force of gravity~~ ~~of gravity on the moon. of the moon towards the earth~~ centrifugal tendency on the moon. as $\frac{1}{4000}$ × acc. of gravity on earth.

But taking moon's distance as 60 earth's radius $(R_e/R_m)^2 = \frac{1}{3,600}$.

So there was a discrepancy *

Actually N. took ~~R~~ R_e from Galileo Dialogo and is too ~~small~~ large.

Also problem of attraction of extended spherical earth not solved.

In 1666 N. does not clearly discuss gravitational force as such.

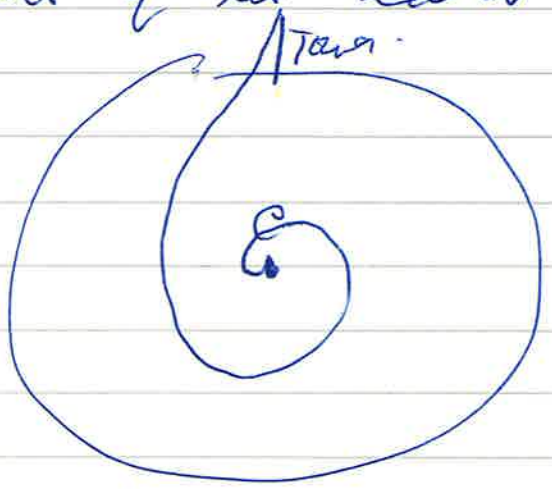
He thinks of circular motion as a stable equilibrium (cf. Huygens) but this implicitly assumes that force of gravity is balancing the centrifugal tendency.

Newton did not return to dynamics until 1679.

Background to the Principia

Idea of universal gravitation was widely discussed in the 1670's. Of Borelli, Hooke, Wren, Halley &c. Not explicit account given by Hooke in his work, 'Attempt to prove the Motion of the Earth' in 1674.

In 1679 Hooke, who had succeeded Oldenburg as Secretary of the R.S. wrote to Newton inviting him to resume Correspondence with the R.S. and asking for his opinion on Hooke's hypothesis that planetary motion is compounded of a tangential motion & an attractive force towards the central body.
Newton declined to enter into correspondence but in his reply suggested an experiment to prove the rotation of the earth - A body dropped from a great height fall not to the west but to the East and — orbit would speed down to centre of the earth



Hooke replied path curved to a sort of ellipse rather than a spiral to. the body would orbit the Globe.

N.B. Grav. field of a sphere solved
only in 1685 . by Newton -

Newton replied, agreeing with his error, but said: assuming constant force of gravity that orbit would not be an ellipse
Hooke replied that this seemed right but he believed inverse sq. law - not constant force of gravity.
Newton did not answer the reply but privately wrote a paper showing that for inverse sq. law path would be an ellipse

In 1684 Halley visited Newton in Cambridge and specifically asked him what would be the orbit under the inverse sq. law. Newton replied "an ellipse". H. said how do you know? N. said I computed it but could not find his 1679 paper. A few months later N. sent to Halley a short tract de Motu in which Kepler's 1st 2 3rd laws are derived from the inverse sq. law.
The de Motu was revised & expanded and in 1687 became

Principia (Philosophiae Naturalis Principia Mathematica.)

(2nd ed. 1713, 3rd ed. 1726.
edited by Roger Cotes / ed. by Henry Pemberton)
English translation by Motte. 1729.

Summary of Principia

Newton's Preface to 1st ed.

'I offer this work as the Mathematical principles of philosophy for the whole burden of philosophy seems to consist in this – from the phenomena of motions to investigate the forces of Nature and then from these forces to demonstrate the other phenomena;'

In 2nd ed very short Preface by Newton followed by long Preface by Cotes – main object was to combat the still flourishing Descartes vortex theory; the Preface advocates 'action at a distance' and that gravity is an innate property of matter (both denied by Newton apparently in the General Scholium)

|| For Newton's responses in letters see p. 633/634 Cajori's notes. See also query 31 in 2nd ed of the Opticks (1717). Cotes preface is also a resounding affirmation of the idea of Universal gravitation

In 3rd ed, v. short Preface by Newton

Principia starts with

Definitions quantity of matter etc

particularly in the Scholium to the definitions

Time, Space – v. famous passages (p. 6)

– rotating bucket expts, 2 globes joined by a string. etc.

Axioms, or Laws of Motion to 3 Laws

V.B. No Principia does not formally use the Calculus (plurals) but the method of ultimate ratios is employed when it is needed equivalent to the Calculus.

The Mathematical Language of the Principia is Geometrical rather than Analytical

Book I The Motions of Bodies.

developed in a series of theorems, problems, lemmas, & scholia.

1. orbital motions about a fixed centre.
~~2. The 2-body problem~~ is given a very complete treatment, in particular the inverse sq. law → Kepler's laws.
~~(corrected for motion finite mass of~~ the Sun)

2. The 2-body problem is now discussed (correction to Kepler's 3rd law)

3. In Theorem 2~~4~~6 (Prop. 66) the 3-body problem is tackled. This is the theorem which is later used to discuss
   a) the perturbations of the moon
   b) the theory of the tides
   c) the precession of the equinoxes.

4. Theorem 30 (Prop. 70), Newton begins to discuss the vital problem of the attraction of an extended sphere on a particle (corpuscle) — extended in theorem 42 et seq to the attraction of non-spherical bodies

5.) Book I concludes with discussion of laws of refraction & reflection for corpuscles — application to light comes in a scholium.

Book II The Motion of Bodies (in resisting Medium)

N. discusses motion of bodies resisted in proportion to v and to v^2.

In Prop. 36 he considers the problem of motion of water thro hole in bottom of a cylindrical vessel, but Newton had no real mastery of hydrodynamics

In Prop 41 & 42 he considers the motion propagated thro' a fluid and shows you cannot have rectilinear propagation.

In Prop 49 he calculates velocity of a pulse in elastic medium

In the scholium to this section N. applies his results to light & sound — light cannot be a wave motion

But vel. of sound does not agree with experiment — N. did not allow for adiabatic compression in a sound wave (cf Laplace's solution of this problem)

But N. fudges the theoretical value for the velocity of sound by an ad hoc allowance for the crassitude of the air particles thro which sound propagates instantaneously.

Finally N. devises the ancient notion of fluids & vortex motion

In this I choked N. offers clues to the Cartesian vortex theory of planetary motion — says Kepler's 3rd law cannot be falsified

" The hypothesis of vortices is widely received both astronomical phenomena, and rather serves to perplex than explain the heavenly Motions ".

En Bk II N. also discusses a number of his own experiments on pendulum and to falling bodies

↓ in air

↓ in water

References of Rules of Reasoning

W. Whewell: The Philosophy of the Inductive Sciences Vol 2. pp 278-292, 2nd ed (1847)

Rule 1. Vera Causa — may refer to 'familiar causes rather than 'true' causes.

cont'd on Rule 2.

R. 3. appears to encourage us to accept a law as universal even where it has not been tried

R. 4 warns that laws may be inaccurate, even where they have been tried

Purpose of rules is to justify tentative generalizations

R.M. Blake, C.J. Ducasse and E.H. Madden 'Theories of Scientific Method: The Renaissance through the 19th Century. (1960) pp 119-143

E.A. Burtt The Metaphysical Foundations of Modern Physical Science 1st ed. 1924 p. 202 ff.

J. Losee A Historical Introduction to the Philosophy of Science 1st ed. 1972. Ch 8., especially pp. 92-93

J.E. McGuire: "Newton on the 'Analogy of Nature'" St. Hist. Phil. Sci 1 (1970) 3-58

Book III System of the World (in mathematical Treatment)

Rules of Reasoning in Philosophy

1) No more causes than are required to explain phenomena i.e. simplicity in Nature

2.) Same effects have same causes.
(used to argue for universal gravitation)

3.) Qualities of bodies always present deemed to be universal — i.e. induction justified.
Analogy of Nature

N.B. 'Not that I affirm gravity to be essential to bodies'.

4.) Propositions inferred from phenomena are to be held true until refuted
— Conjectures and refutations.

"This rule we must follow, that the argument of induction may not be evaded by hypotheses".

Phenomena. Kepler's 2nd and 3rd laws apparently for Jupiter's planets, Saturn's planets, the 5 primary planets and the moon (2nd law only).

N. then deduces a universal law for gravitation and elliptic orbits of planets

N - made the hypothesis (P-419)

'The Centre of the system of the world is immovable'.

In Prop-19 N. discusses the figure of the earth due to its rotation — centrifugal force will cause equatorial bulge — problem not really solved until 18th C. by Clairault, Laplace etc.

What is equilibrium shape for a sea ~~of uniform depth~~ over a spheroidal earth — condition for sea to be of uniform depth is that earth is also spheroidal.

N. then applies Prop. 66, Bk I to explain

1) lunar motions
2.) tides
3.) precession of equinoxes due to action of sun & moon on equatorial bulge.

N. said lunar theory made his head ache.

In Prop 38 N. derives the figure of the moon (assumed fluid) and explains ~~what~~ why moon always turns same face to us (modulo libration)

N. then proceeds to give very complete discussion of orbits of the Comets.

N.B In the Motte translation in modern days N°. The System of the World which was a preliminary draft of Bk III of Principia with most of the mathematical detail omitted

in 1.552 deep discussion of possibility of extended satellites

→ This is Bk II of de Motu Corporum (1685), a much expanded version of the 9-page 1684 tract de Motu-

General Scholium to the 2nd.

1. The hypothesis of vortices is pressed with many difficulties

In particular motion of comets is quite not accountable on vortex theory.

V. argues lies theory softens the existence of God.

2. "This most beautiful system of the sun, planets and comets could only proceed from the counsel and dominion of an intelligent and powerful Being"

God is ~~often~~ omniscient & intelligent

— (Space is sensorium of God)

"Hitherto I have not been able to discover the cause of these properties of gravity from phenomena, and I frame no hypothesis"

10. about gravity, not in general?

First paragraph. Looks at explanation by certain most subtle spirit which pervades and lies hid in all gross bodies

— 10. Or vortex.

N.B. Hooke died in 1703 then N. felt free to publish his work on colours?!

Subtitle of Opticks

A treatise of the reflexions, refractions, inflections and colours of light

In 1st ed. N. attached two treatises of the species and magnitude of curvilinear figures

In N's Advertisement to the 1st ed. he made oblique reference to Leibniz plagiarism wrt. the Calculus (p. 122)

In second ed. Advertisement N: "I do not take gravity to be an essential property of bodies — —

1692 Fire destroyed manuscript of Opticks as it then existed.

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cf A.I. Sabra: Theories of light from Descartes to Newton (1967)

G. Cantor: Theories of light in Britain and Ireland 1704–1840

The Opticks 1st ed. (English) 1704 (16 queries)

1st Latin ed. 1706 7 new queries (25–31 2nd English)
2nd English ed. 1717 queries 17–24 in the aether (explains general gravitation & 2nd ed Principia.)
3rd " " 1721
4th " " 1730
↳ brought out after Newton's death with some minor corrections by Newton.

Work on colours one of Newton's major preoccupations throughout his life.
The Opticks is therefore based on much earlier research. Work on experimental physics influence on Franklin etc in 18th C.
Principia terminates the fullness of mechanics. But Opticks marks a new beginning in theory of colours, diffraction, atomic force speculation etc.
Opticks in a sense anticipates wave-particle duality thru 'theory ... ' that throws confusion into fits of easy reflection and transmission (refraction).
Diffraction and interference colours in thin plates first described by Grimaldi (1665) and Hooke in his Micrographia (1665) respectively, but the latter was much more precisely investigated by Newton (Newton's rings).

N.B. ok at minimum deviation would
shape not be changed if white
light had a constant refractive index
if account is taken of the differing
angles of incidence of the prism

Book I, Part I

'My design in this book is not to explain the properties of light by hypotheses, but to propose and prove them by Reason and Experiments'

8 Definitions rays, primary colour associated with homogeneal light (= definite refrangibility)

Continues with 8 Axioms summarizing elementary laws of reflection & refraction

N. then affirms (Prop. 1)

'Light which differs in colour, differs also in degree of refrangibility.'

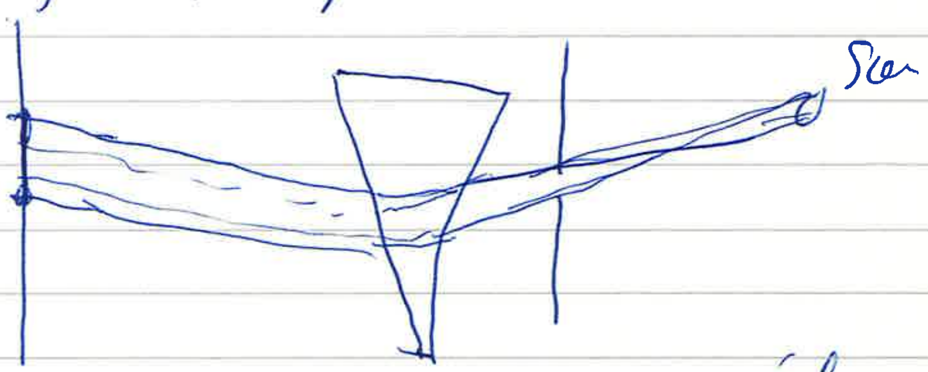
The proof by Experiments

Then follows the famous prism experiments..

image of a small hole in shutter admitting sun light is spread out into an oblong shape. i.e. a spectrum is formed

Prop II The light of the Sun consists of Rays differently refrangible

* Expt. 1



The shape of the image is what surprised Newton

See also Exp 5
with curved pieces

Expt. 6 is the crucial expt. of using a second prism to refract light from a selected part of the spectrum produced by the 1st prism — no further dispersion is produced

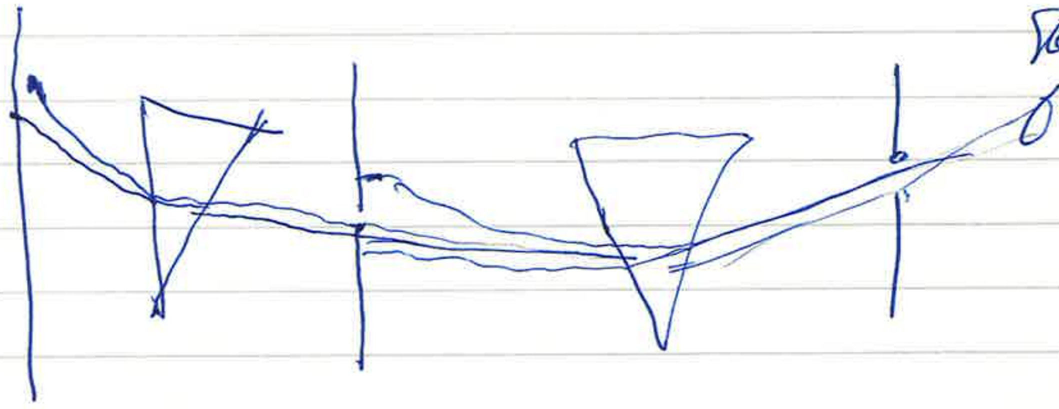


Fig.

Prop VII The perfection of telescopes is ~~[illegible]~~ limited by the different refrangibility of the rays of light.

p102 "Seeing therefore the improvement of telescopes of given lengths by refraction is desperate, I contrived heretofore a perspective by reflexion, using instead of an object-glass a concave metal."
→ Newtonian reflecting telescope.

Bk 1 Part II This is mainly concerned with mixing of colours to produce white light. the theory of the rainbow and the colours of natural ~~bodies~~ (due to selective reflection.)

N. asserts (Prop 1) that colours are not produced by a modification of light as thought by Hooke; others colours were present in white light – revealed by the prism

N B modern theory does not agree with this cf Fourier resolution of a pulse

Book II, Part I is concerned with colours of thin transparent bodies (plates)

Here are described the phenomena of Newton's rings.

Book II Part II is entitled

'Remarks upon the foregoing Observations'

emphasises again white as a mixture of colours, immutable relation between colours & degree of refrangibility — concludes (p. 244) 'the Science of Colours becomes a Speculation as truly mathematical as any other part of Opticks'

Book II Part III discusses relationship of permanent colours of objects to colours of thin surface plates in objects — very thin specimens are transparent — do not reflect light.

In Prop 11 N. says light from the sun takes 7 or 8 minutes to reach earth from the sun. (refers to Roemer's observations of eclipses of satellites of Jupiter.)

Then in Prop 12 N. tries to explain colours in thin plates by his theory of 'fits'. (p. 278) Defined on p. 281

"The returns of the disposition of any ray to be reflected I will call its Fits of easy reflexion and those of its disposition to be transmitted its fits of easy Transmission, and the

Enlarged by Young — due to large p.d.
no interference effects in white light.
appears like a spurious effect due
to scattering of light at the surface
of the mirror.
cf Mach on Optics. , Brewster's life of Newton

space it passes between every returns & the next returns the Interval of the Fits (is wonderful)

p. 482 Light is in Fits --- before its incidence on transparent bodies. And probably it is put into such fits at its first emission from luminous bodies!"

Prop 18 Interval of Fits for yellow/orange light is $\frac{1}{89000}$ inch

Book II Part IV is entitled

"Observations concerning the reflexions & colours of thick transparent polished Plates" (cf Fabry-Perot Interferometer or Lummer-Gehrcke plate.)?

Book III Observations concerning the inflexions of Rays of light and the colours made thereby.
- refers to Grimaldi's work (on diffraction)

N. proceeds to summarize 11 observations on these phenomena and then on p 338 he breaks off. "When I made the foregoing observations, I designed to repeat most of them with more care and exactness, and to make some new ones for determining the manner

how the rays of light are bent in their passage by bodies, for making the fringes of colours with the dark lines between them. But I was then interrupted and cannot now think of taking these things into further consideration. And since I have not finished this part of the design, I shall conclude with proposing only some Queries, in order to a further search to be made by others.

Queries

1. Do not Bodies act upon light at a distance, and have bend the rays.

2. Do not rays which differ in refrangibility also differ in their flexibility.

5. Do not bodies & light act mutually – bodies ~~to~~ emit reflect refract, & reflect light, but light heat bodies and put "their parts into a vibrating motion wherein heat consists."

8. Do not all fix'd bodies when sufficiently heated emit light, due to the "vibrating motions of their parts

9. Is not fire a body heated so hot as to emit light

12. Do rays of light fall on the eye exactly <u>vibrations</u> or the retina

13 are the <u>sensations</u> of colour similar to sensations to sound

14. Darwin ? denied of classes confused with the case of sounds.

Query <u>17</u> introduces earlier classes

17. When a ray of light falls on the surface of a polished body may it cause a vibrations or waves to enacted on the refractory or reflecting Medium there vibrations, undertake the ray of light and put them into the appropriate Fits. The rays are "alternately accelerated and retarded by the vibrations certainly does".

18. Introduces a subtler medium than air to account for the vibrations — the aether

20 Aetherial medium extends beyond bodies so refraction takes place gradually. — also Explains diffraction phenomena.

21 Is not the aether the cause of gravity?

22 Is not the <u>resistance</u> offered by the aether to planets & comets negligible

23 Are not aetherial vibrations propagated thro the Solar Rays to Earth varies

Received 29 Bartholinies (Erasmus)

1669